PATENT

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SCALING METHOD AND APPARATUS FOR DISPLAYING SIGNALS

BACKGROUND

[0001] The present invention relates to signal display systems. More specifically, the present invention relates to the method and apparatus for displaying signal waveforms of data transmissions.

[0002] Traditionally, in optical digital communication systems, non-return-to-zero (NRZ) modulated signals have been used at rates as fast as ten Gbs (Giga bits per second). However, as the speeds and distances for optical transmissions increase, return-to-zero (RZ) modulated signals become more desirable for various reasons. NRZ modulated signals are digital signals in which each binary value (a low or a high state represented by a zero (0) and one (1), respectively) are transmitted by a specific and constant direct-current (DC) voltage. RZ modulated signals are digital signals that, at each bit, or bit period, the value of the signal returns to zero. Figure 1 illustrates a sample signal bit sequence "10110" sent modulated as an NRZ signal 10 and also as an RZ signal 12. A clock signal 14 is also illustrated, the clock signal dictating the period of each bit of the signals. Note that, unlike the NRZ modulated signal 10, the RZ modulated signal 12 represents a digital value "1" with a combination of high DC voltage, V_{HIGH}, for a high portion 16 (having a first duration) of a period and a low DC voltage, V_{LOW}, for a low portion 18 (having a second duration) of the period. The RZ modulated signal 10 has a duty cycle defined as a ratio of the first duration 16 to one bit period. For

the purposes of illustration only, the signals 10 and 12 are illustrated as square waves.

[0003] Both the NRZ modulated and RZ modulated signals are analyzed, in part, by displaying the waveforms of the signal on an oscilloscope ("scope"), and in particular multivalue waveform display format. For example, test equipment receives an input signal (NRZ modulated or RZ modulated) and automatically scales ("autoscale") the scope to show a multiple the waveforms (bits) of the input signal. To automatically scale the scope, the test equipment determines a range of signal strength values, typically in volts. This range is usually displayed as the Y-axis on the display. Further, the test equipment determines the period of a bit, the bit period, of the input signal. The period is typically measured in units of fractional seconds such as a picosecond (ps). Then, the measured period is used to display one or more bits of the input signal.

[0004] Figure 2A illustrates a sample multivalue format display of an NRZ modulated input signal in an eye-diagram 11 format. In the eye-diagram 11, multiple bits (1's and 0's) are overlaid; this is illustrated using thick gray lines. The Y-axis displays the voltage ranging from V_{LOW} to V_{HIGH}. For autoscaling purposes, the voltage range is easily measurable from the input signal. As for determining the bit period to autoscale the X-axis, techniques exist to determine the bit period for NRZ modulated input signals. For example, some techniques detect subsequent NRZ transition periods to determine the bit period. However, such techniques for autoscaling the NRZ modulated signals are not well suited for RZ modulated input signals. For example, Figure 2B illustrates a sample multivalue format display 13 of an

RZ modulated signal. Note that the RZ multivalue signal 13 does not include NRZ transition periods; rather, the RZ multivalue signal 13 includes zero spaces at each bit period whereas the eye diagram 11 (NRZ multivalue signal 11) of Figure 2A does not. A zero space is a period of time with no signal value (or data points) above certain threshold, V_{THRES}.

[0005] Accordingly, the existing NRZ autoscaling methods are ill suited to scale RZ signals. There is a need for a method and apparatus to autoscale incoming RZ modulated signals for displaying on test equipment.

SUMMARY

[0006] These needs are met by the present invention. According to one aspect of the present invention, a method of displaying an input signal is disclosed. First, the input signal is sampled. The sampled signal is searched for a zero space pattern. Then, a first zero space is located and a second zero space, following the first zero space, is located. A bit period of the input signal is calculated. Finally, the input signal is displayed using the calculated bit period as the basis for a scale.

[0007] According to another aspect of the invention, an apparatus for displaying an input signal is disclosed. The apparatus includes a processor and a storage connected to the processor. The storage includes instructions for the processor to sample the input signal; to search for a zero space pattern in the sampled signal; to locate a first zero space; to locate a second zero space, following the first zero space; to calculate bit period of the input signal; and to display the input signal using the calculated bit period as the basis for a

scale.

[0008] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Figure 1 illustrates a non-return-to-zero (NRZ) modulated signal and a return-to-zero (RZ) modulated signal;

[0010] Figure 2A illustrates an eye diagram as a multivalue diagram of an NRZ-modulated signal;

[0011] Figure 2B illustrates a multivalue diagram of an RZ-modulated signal;

[0012] Figures 3A through 3D are flowcharts illustrating one embodiment of the method of the present invention;

[0013] Figures 4A to 4E show various sample signal configurations; and

[0014] Figure 5 is a simplified diagram illustrating an apparatus in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

[0015] As shown in the drawings for purposes of illustration, the present invention is embodied in a method of and apparatus (for example, a testing equipment) for displaying an incoming signal ("input signal") by automatically scaling the X-axis by determining the bit period, or frequency, of the incoming signal. In summary, the technique includes a first step of sampling the signal. The sampled signal is searched for a zero space pattern. Then, a first zero space is

located and a second zero space, following the first zero space, is located. A bit period of the input signal is calculated. Finally, the input signal is displayed using the calculated bit period as the basis for a scale.

[0016] A flowchart 20 of Figure 3A illustrates one embodiment of the technique of the present invention. Referring to Figure 3A, an input signal is sampled. This step is illustrated using procedural step box 22 ("Step 22"). The sampled signal is searched for zero space patterns. Step 30. Then, a first zero space is located within the input signal. Step 50. Next, a second zero space is located within the input signal. Step 70. The locations of the two zero spaces are used to calculate the bit period of the input signal. Step 90. The calculated bit period is used to display the input signal. Step 92. Figures 3B to 3D illustrates the flowchart 20 of Figure 3A in more detail.

Sampling the Input Signal

[0017] Referring to Figure 3B, the step 22 of Figure 3A is illustrated using dashed box 22 of Figure 3B comprising a step of initializing an offset. Step 24. For example, assume that the input signal is introduced to the testing equipment at some initial instant in time, T_0. Then, the testing equipment begins to sample beginning at some offset, T_{OFFSET}, from T_0. The sample represents a segment of the incoming signal, the segment is referred to as the sampled signal. An initial scale, T_{SCALE} of some predetermined period is set, for example, at two picoseconds, 2 ps. Then, a number of samples are taken from T_{OFFSET} for a duration, $T_{DURATION}$, that is a multiple of the scale. Step 26. For example, if 3,000 samples are taken, for a duration of ten times the T_{SCALE}, then samples

are taken at intervals of 6.67e-3 ps that is calculated as

$$T_{INTERVAL} = (2 \text{ ps} * 10) / 3{,}000$$

Search For a Zero Space Pattern

[0018] The step 30 of Figure 3A is illustrated using dashed box 30 of Figure 3B including more detail. The sampled signal is examined and searched for zero space patterns. Step 31 of Figure 3B. Possible zero space patterns of the sample signal are illustrated using Figures 4A through 4D. Referring to Figure 4A, a sampled signal 31a is illustrated having an incomplete zero space pattern. Figures 4B and 4C illustrate other sampled signals 31b and 31c, respectively, with other incomplete zero space patterns. Figure 4D illustrates another sampled signal 31d. Here, the sampled signal 31d has a complete zero space pattern as illustrated. The sampled signal, in general, may have no zero space pattern, one or two incomplete zero space patterns, one or more complete zero space patterns, or a combination of complete and incomplete zero space patterns. Figure 4E illustrates a sampled signal 31e having two complete zero space patterns.

[0019] Referring again to Figure 3B, if a zero space is not found within the sample signal (decision step 32), then the sample signal is tested for applicability of NRZ modulated signal autoscaling methods. Decision Step 34. The test for applicability of NRZ modulated signal autoscaling methods is known in the art. For example, such test involves locating two consecutive crossing regions in an eye diagram. The crossing regions are illustrated by Figure 2A using reference numbers 17 and 19. When these two regions are detected, the period of

the NRZ signal, for the purposes of autoscaling, is the distance, in the temporal scale, between these two regions.

[0020] If the NRZ modulated signal autoscaling methods are applicable, then the NRZ modulated signal autoscaling techniques are used to autoscale the X-axis for displaying the input signal. Step 36. Various techniques are known in the art to autoscale and display NRZ modulated signals and are implemented in instruments such as Agilent 83480A Digital Communication Analyzer by Agilent Technologies, Inc. and Tektronix CSA8000 Digital Sampling Oscilloscope by Tektronix, Inc..

[0021] If the NRZ modulated signal autoscaling methods are not applicable, then the scale is adjusted (step 38), samples taken with the adjusted scale (Step 26), and the steps 31, 32, and 34 are repeated. To adjust the scale, the current scale can be increased by 50 percent. For example, if the current scale, T_{SCALE}, is increased from two picoseconds to three picoseconds. However, if the adjusted scale is equal to or greater than a limit, then the autoscale operation terminates. Steps 40 and 42.

Locate a First Zero Space

[0022] If a zero space is found within the sample signal at decision step 32, then the zero space is located within the sampled signal. Step 50 of Figure 3A. The step 50 of Figure 3A is illustrated in more detail in Figure 3C and is connected to Figure 3B via connector A. Referring to Figure 3C, the offset and the time scale are adjusted, if necessary. Step 52. For example, if the sampled signal had only incomplete zero space, then adjustments of the offset, time scale, or both may be necessary. If the adjustments are made, then the input signal is re-

sampled.

[0023] The sampled (or re-sampled) signal is searched for a first zero space. Step 54. If found, the first zero space is defined by a first transition X_1 and a second transition X_2. The first transition X_1 and the second transition time X_2 of the first zero space are illustrated in Figure 4E. If the first zero space is not found, decision step 56, then the time scale is adjusted and the input signal is sampled again. Step 58. For example, the time scale can be increased by 50 percent. Then, the steps 54 and 56 are repeated. If the adjusted time scale is equal to or greater than a limit, then the autoscale operation terminates. Steps 60 and 62. The first transition, X_1 is where value of the input signal is more than a threshold value, V_{THRES}, before the first transition, X_1, but less than the threshold value, V_{THRES}, after the first transition, X_1. The first transition, X_1, is the first such transition following the offset. The second transition, X_2, is where value of the input signal is less than the threshold value, V_{THRES}, before the second transition, X_2, but more than the threshold value, V_{THRES}, after the second transition, X_2, the second transition, X_2, being the first such transition following the first transition, X_1.

Locate a Second Zero Space

[0024] If the first zero space is found within the sample signal at decision step 56, then the sampled signal is searched for a second zero space. Step 70 of Figure 3A. The step 70 of Figure 3A is illustrated in more detail in Figure 3D and is connected to Figure 3C via connector B. Referring to Figure 3D, the sampled (or re-sampled) signal is searched for the second zero space. Step 74.

If found, the second zero space is defined by a third transition, X_3, and an fourth transition time X_4. The third transition, X_3, is where value of the input signal is more than a threshold value, V_{THRES}, before the third transition, X_3, but less than the threshold value, V_{THRES}, after the third transition, X_3. The third transition, X_3, is the first such transition following the second transition, X_2. The fourth transition, X_4, is where value of the input signal is less than the threshold value, V_{THRES}, before the fourth transition, X_4, but more than the threshold value, V_{THRES}, after the fourth transition, X_4, the fourth transition, X_4, being the first such transition following the third transition, X_3.

[0025] If the second zero space is not found, decision step 76, then the time scale is adjusted and the input signal is sampled again. Step 78. For example, the time scale can be increased by 50 percent. Then, the steps 74 and 76 are repeated. If the adjusted time scale is equal to or greater than a limit (decision step 80), then the input signal is displayed using the scale from the first zero space only. Step 82. That is, the bit period is set as the duration of the first zero space, for $X_2 - X_1$. Then, the time scale (X-axis) is set at some multiple of the but period, for example, 1.5 times the bit period when displaying the input signal.

Calculate the Bit Period and Display the Input Signal

[0026] If the second zero space is found within the sample signal at decision step 76, then bit period is calculated as period $X_3 - X_1$. Step 90. Then, the time scale (X-axis) is set at some multiple of the but period, for example, 1.5 times the bit period when displaying the input signal to ensure that a complete period is

displayed. Step 92.

Apparatus and Medium

[0027] Figure 5 illustrates an apparatus 61 according to one embodiment of the present invention. The apparatus 61 includes a processor 64 and storage 66 connected to the processor 64. Also connected to the processor 64 is a display 68. The storage 66 includes instructions for the processor to implement the present inventive technique including instructions for the processor 61 to sample the input signal; to search for a zero space pattern in the sampled signal; to locate a first zero space; to locate a second zero space, following the first zero space; to calculate bit period of the input signal; and to display the input signal using the calculated bit period as the basis for a scale.

[0028] The storage 66 is typically a machine readable medium such as a magnetic disc, optical disc, read only memory (ROM), random access memory (RAM), harddrive, compact disc (CD), flash memory, and solid state memory.

[0029] Although specific embodiments of the invention have been described and illustrated, the invention is not to be limited to the specific forms or arrangements of parts so described and illustrated. The invention is limited only by the claims.